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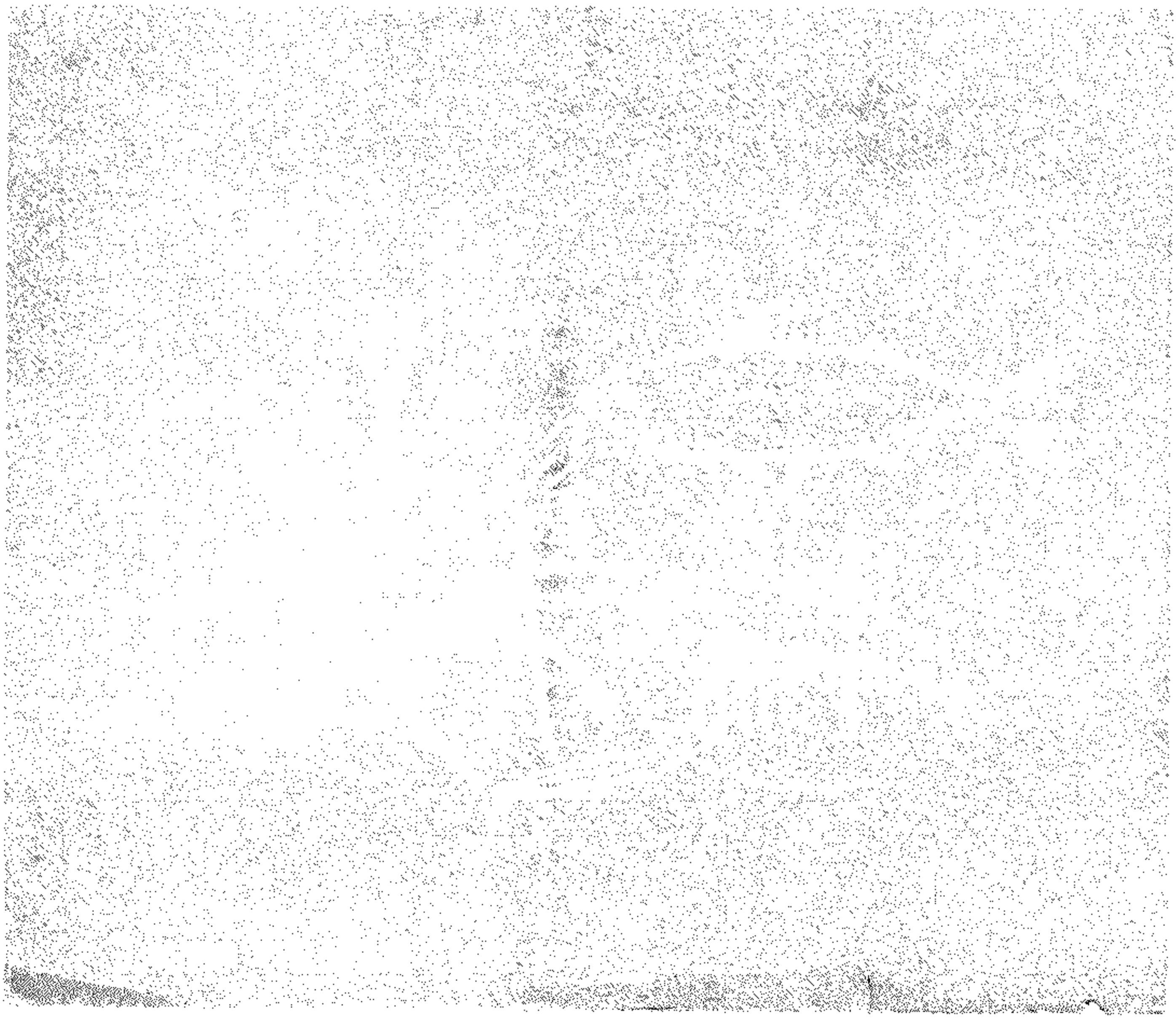

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A REVIEW OF THE LIVING RESOURCES OF THE CENTRAL INDIAN OCEAN

S. JONES AND S. K. BANERJI

Central Marine Fisheries Research Institute, Mandapam Camp

ABSTRACT

In this paper the potential resources of the Central Indian Ocean bordering India, Pakistan, Ceylon, Burma, west coast of Thailand and extending upto 45° S latitude and covering an area of about 25 million square kilometres have been reviewed and the potential yield of the area has been assessed separately for the demersal and pelagic fisheries. The estimated production in 1966 from the area was about 1·5 million tonnes. A minimum potential yield of about 4·0 million tonnes has been assessed for the area.

TOPOGRAPHY

THE area considered here is bounded on the west by the longitude 61° 4′ E from the southern tip of intersection of Iran and West Pakistan, on the south by the 45° S latitude and on the east by the longitude 95° 1′ E from 45° S latitude upto 6° 4′ N latitude and then running along the 6° 4′ N latitude itself upto the Thailand-Malaysia border (latitude 6° 4′ N, longitude 100° 1′ E). This section of the Indian Ocean borders the coast line of West Pakistan, India, East Pakistan, Burma and the west coast of Thailand and contains the following main island groups: (1) Ceylon, (2) Andaman, (3) Nicobar, (4) Laccadives and Minicoy, (5) Maldives, (6) Chagos Archipelago and (7) St. Paul and Amsterdam (Fig. 1). The total area of this section, here called Central Indian

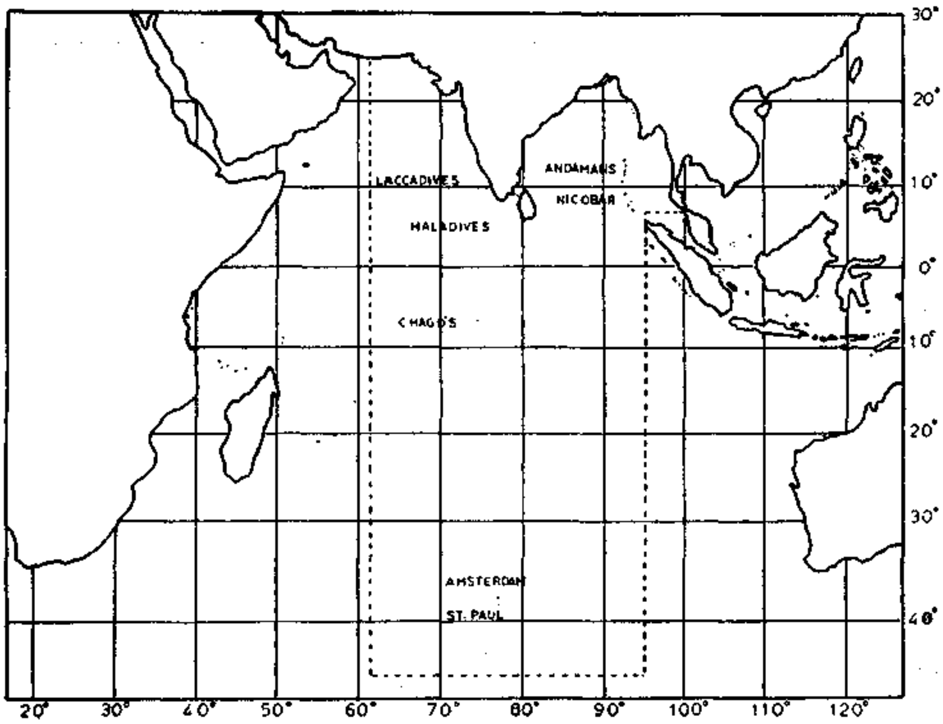

FIG. 1. The Central Indian Ocean region indicated by dotted lines.

Ocean region, is estimated at about 24·8 million square kilometres. Following the nomenclature of the International Hydrographical Bureau (Monaco) regarding the limits of oceans and seas, the details of the areas of the various seas and oceans contained in the region are given in Table I, both in square miles and square kilometres.

TABLE I

Ocean areas

Region		Area (in sq. miles)	Area (in sq. km.)
Arabian Sea	..	10,60,676	27,47,151
Laccadive Sea	..	2,91,226	7,54,275
Bay of Bengal	..	8,55,415	22,15,523
Andaman or Burma Sea	..	2,06,760	5,35,508
Malacca Straits	..	31,149	80,676
Indian Ocean—			
(*a*) Portion above Equator	..	6,80,492	17,62,473
(*b*) Portion between 0° and 15° S	..	23,51,400	60,90,121
(*c*) Portion between 15° and 30° S	..	21,95,400	56,86,082
(*d*) Portion between 30° and 45° S	..	18,89,518	48,93,848
TOTAL	..	95,62,036	2,47,65,657

The region includes wide areas of the continental shelf as shown in Table II, both in square miles and square kilometres.

HYDROGRAPHY

Currents

In the northern part of the Indian Ocean the circulation is largely influenced by the surrounding land masses. In the southern part there is an anti-clockwise circulation which resembles those in the Pacific and Atlantic and which comprises the South Equatorial, Mozambique, Agulhas Currents, the west-wind drift and the West-Australia Current. During the winter months when the north-east monsoon winds prevail over the northern part of the ocean the North Equatorial Current is well developed while to the south of it the Equatorial Counter-Current flows eastward with its axis at about 5° S. Along the African coast south of the Gulf of Aden, the North Equatorial Current is deflected to flow southwards. In the summer months when a low pressure area is established over Central Asia and the south-west monsoon wind blows across the ocean, the North Equatorial Current is replaced by the Monsoon Current which flows from west to east. Along the African coast from 10° S northwards, the flow is directed towards the north and much water from the South Equatorial Current crosses the Equator. This flow along the African coast is known as the Somali Current. In this Somali Current flowing into the Arabian Gulf, the velocity exceeds 2C0 cm./sec. (4 kt). The Equatorial Counter-Current cannot be distinguished in this season.

In this basic flow pattern, eddies develop either in between two current systems or in any basic current. The eddies formed between the North Equatorial Current and the Equatorial Counter-Current have a counter-clockwise direction while they are clockwise between the Equatorial ar ' the South-West Monsoon Currents.

TABLE II

Continental shelf area

Area	Square miles		Square kilometres	
	upto 200 m.	upto 50 m.	upto 200 m.	upto 50 m.
1	2	3	4	5
1. *Arabian Sea and Laccadive Sea*				
(*a*) West Pakistan ..	21,002	7,652	54,935	19,819
(*b*) Gujarat ..	38,368	25,023	99,373	64,810
(*c*) Maharashtra ..	40,447	9,850	104,758	25,512
(*d*) Goa ..	3,855	1,100	9,984	2,849
(*e*) Mysore ..	9,835	3,064	25,473	7,936
(*f*) Kerala ..	13,877	4,853	35,941	12,569
(*g*) West Coast of Madras ..	3,010	326	7,796	844
2. *Bay of Bengal* ..				
(*a*) East Coast of Madras ..	12,979	8,653	33,616	22,411
(*b*) Andhra ..	11,986	6,412	31,044	16,607
(*c*) Orissa ..	9,123	6,566	23,629	17,066
(*d*) West Bengal ..	8,827	3,836	22,862	9,935
(*e*) East Pakistan ..	25,311	14,384	65,555	37,255
(*f*) West Coast of Ceylon ..	5,243	3,485	13,579	9,026
(*g*) East Coast of Ceylon ..	4,518	1,819	11,702	4,711
3. *Burma Sea and Malacca Straits*				
(*a*) Burma ..	83,977	41,854	217,500	108,402
(*b*) West Coast of Thailand ..	22,417	8,093	58,060	20,961
4. *Islands*				
(*a*) Andamans ..	5,918		15,328	
(*b*) Nicobar ..	281		728	
(*c*) Laccadives ..	1,674		4,336	
(*d*) Maldives ..	2,878		7,454	
TOTAL ..	325,526		843,653	

In the southern part of the Indian Ocean a great anti-cyclonic system of currents appears to prevail, comparable to the corresponding systems of the south and the north Atlantic Oceans, except that it is subjected to annual variations. Between South Africa and Australia the current is directed, in general, from west to east. In the southern summer the current bends north before reaching the Australian continent and is joined by a current which flows from the Pacific to the Indian Ocean to the south of Australia. In winter the current appears to reach up to Australia and to continue in part towards the Pacific along the Australian south coast.

During the south-west monsoon the circulation pattern in the Arabian Sea is clockwise and a strong southward drift is found along the west coast of India (especially in the region, Calicut to Karwar). By the end of the south-west monsoon this flow is weakened and a northward coastal current associated with sinking is found along the coast by December. In the Bay of Bengal along the east coast of India a north-easterly current flows during the period January to July and a south-westerly current flows during the period August to December.

The Equatorial Undercurrent in the Indian Ocean is well developed in the latter part of the north-east monsoon and continues to be present till the end of May. It is similar in many respects to the undercurrent in the Atlantic and Pacific, but for its asymmetry about the Equator.

Upwelling

Wyrtki (1961) has postulated that an examination of the oceanographic conditions in the region between Java and Australia during the south-east monsoon season shows that the main upwelling area in this region is situated along the coast of Java and Sumbava and not along the north-west Australian shelf, as was previously assumed. During the north-west monsoon over this area, when the equatorial low pressure trough lies to the south of Java and when the Java Coastal Current flowing east along the south coast of Java is developed, the South Equatorial Current shifts to the south. Along the boundary of these two currents upwelling seems to develop.

The zones of upwelling in the Equatorial region according to Ovchinnikov (1960) as cited by Vinogradov and Voronina (1962) during north-east monsoon are between 50° E and 110° E meridians around a mean latitudinal axis of 7° S. North of the Equator the zones are scattered and they are at latitudes of 5° to 6° N around the meridians of 58° to 70° E.

Along the Somali Coast, during the Somali Current season (south-west monsoon), strong upwelling occurs and the temperature falls even to 14° C. at the surface. The only other place in the world ocean, where such low surface temperatures are found at such low latitudes, is the Peruvian coast and even there it is uncommon to find surface temperatures lower than 18° C., within 10° off the Equator.

During the pre-monsoon and early south-west monsoon season strong upwelling is found along the west coast of India, the maximum intensity being in the region Calicut to Karwar. The overall divergence caused in the Arabian Sea during monsoon, the prevalent southward coastal drift and to a certain extent the prevalent wind systems are attributed as the cause for the above phenomenon.

La Fond (1958) has observed that the North-Easterly Current flowing along the east coast of India during the period January to July causes upwelling along the coast.

Nutrients

The general distribution of dissolved mineral nitrates and nitrites in the Arabian Sea, Bay of Bengal, Andaman Sea and the open northern part of the Indian Ocean are as follows. The mean value of nitrate is 1 μg.-at. N/l. in surface water, sharply increasing in the thermocline to 15–20 μg.-at N/l and further increasing to 22–26 μg.-at. N/l. with depth. After achieving these concentrations the content of nitrate changes a little. Nitrites are found dissolved as a thin layer in the thermocline layer and under it, up to 2 μg.-at. N/l. depending on zooplankton. In the Arabian Sea the maximum values for nitrite, up to 5 μg.-at. N/l., were found to be at 150–1,500 m., possibly due to the reduction conditions of these waters.

The distribution of dissolved mineral phosphates and silicates in the waters of the northern part of the Indian Ocean is as follows. The amount in surface water ranges from 0·1 μg.-at. P/l. (Arabian Sea and to south-east of Ceylon) upwards and varies with seasons. The maximum content of phosphates in the Arabian Sea and the Bay of Bengal is 2·9 μg.-at. P/l. and to the south of 10° S in the open part of the Indian Ocean the maximum content of phosphates is 2·4 μg.-at. P/l. The content of total organic phosphorus is not more than 0·5 μg.-at. P/l. The distribution of dissolved silicates is 150–160 μg.-at. Si/l. in the Arabian Sea, 140 μg.-at. Si/l. in the Bay of Bengal and 130–140 μg. at. Si/l. in the open northern part of the Indian Ocean.

Oxygen

The quantity of dissolved oxygen at the surface exceeded its solubility by more than 10–20 μg.-at./l. In the regions of upwelling the values were less by 2–3%. In the north-eastern part of the Arabian Sea, the deficit dissolved oxygen reached 4–7% and hydrogen sulphide was discovered in the intermediate layers. In the Arabian Sea layers with less than 20 μg.-at./l. of oxygen were situated at depths of 25–150 m. In the north-eastern part of the Arabian Sea there was no oxygen between 250 m. and the bottom. In the Bay of Bengal the layers with oxygen content of 20–50 μg.-at./l. were at depths of 150–700 m. In the Andaman Sea the quantity of oxygen is constant at 160 μg./-at./l. between 1,500 m. and the bottom (3,200–4,000 m.).

PRIMARY PRODUCTION IN THE INDIAN OCEAN

Primary organic production data reported here are those based on C^{14} technique and methods which give comparable results. The values are expressed as grams carbon per square metre of sea surface.

During the *Galathea* expedition measurements of productivity were made in the Equatorial Indian Ocean, Bay of Bengal and Indo-Malayan waters. During the IIOE measurements were made in the Western Indian Ocean and in the Bay of Bengal. The Central Marine Fisheries Research Institute has made observations on the south-eastern and south-western coasts of India including the Laccadive Sea. The general picture of organic production from the above measurements is as follows:

The Equatorial part of the Indian Ocean was found to have significantly higher production rates (0·20–0·25 gC/m²/day) compared with tropical open seas (Steemann, Nielsen and Jensen, 1957). The IIOE data indicate that north of the Equator the level of organic production increases to the north and west, reaching exceptionally high values off the coasts of Saudi Arabia and West Pakistan. All the values were in excess of 1·0 gC/m²/day with a maximum of 6·4 gC/m²/day observed off the southern tip of Arabia. The Somali Coast also has a high rate of production. Two large areas of low productivity, one extending from 10° to about 40° S lat. and from 80° E long. nearly to the African Coast south of Madagascar and another between 80° and 60° E long. to about 5° S were found (Ryther *et al.*, 1966). All along the west coast of India the rate of production is high (over 1·0 gC/m²/day) especially at the time of upwelling (south-west monsoon season).

On the east coast the rate of production is of a lower order excepting in the shallow regions of the Gulf of Mannar and Palk Bay, where the average rate is over 2·0 gC/m²/day (Prasad and Nair, 1963). In the Bay of Bengal the rate of production on the shelf is 0·63 gC/m²/day and outside the shelf 0·19 gC/m²/day. The Indo-Malayan regions also are characterized by a high rate of production varying between 0·24 and 1·08 gC/m²/day with an average of 0·6 gC/m²/day.

PLANKTON

Phytoplankton

Data on phytoplankton are available for the west coast of India and for the east at a few places. A general picture has been contributed by a few papers based on the material collected during the IIOE.

On the west coast, in the inshore area, the standing crop is of a high order as assessed from net plankton only; the maximum occurs in July or August during the south-west monsoon season. The values (average for 5 years) for net hauls in terms of number reach up to 29,000,000 cells/1; in terms of pigment (Harvey Units) 66,680 HU/m³ and 534 mg. dry weight per haul. The minimum in terms of number falls in November with 200,000 cells/1 and in terms of pigment in February with 10,600 HU/m³; and dry weight never below 100 mg./haul; the maximum values occurring in June to August and minimum in October, November or January.

Taking the nanoplankton also into account, value up to 248,000 HU/m³ have been recorded during the south-west monsoon. Nanoplankton constitutes from 30 to 85%, at times even 96% of the phyoplankters.

On the south-east coast peaks of development occur in March, May and October or February, August and November, depending on the setting in and the intensity of the monsoons. At Madras, the bloom may be at any time between April and June, sometimes August–September; a second pulse of development occurs in November or December during north-east monsoon. At Waltair, the standing crop is richer from April to August than at any other time.

When the two inshore areas on either coast are compared, the standing crop on the east coast does not attain even a fourth of the magnitude of that on the west coast. As regards species composition, while many species of phytoplankton are common to both the coasts, several are not. Further, a few species contribute to the bulk of the crop during the bloom period on the west coast whereas on the east coast no single species could be said to occur in bulk. Another interesting point noticed was that the plankton of the west coast contained more lipids than that of the east coast. The factors responsible for these differences are obscure at present.

The investigations in the inshore areas over the shelf on the west coast indicates that the region is very fertile and productive, comparable with some of the highly productive waters known.

The data for offshore and oceanic regions show that during south-west monsoon the standing crop is richer than during north-east monsoon. However, the magnitude is not as high as over the shelf near shore areas. Another point noticed was that here richer areas alternate with poor areas, probably related to upwelling of nutrient laden waters to the euphotic zone during the south-west monsoon. The plankton-rich areas, to the extent worked out, are given below (based on R. V. *Varuna* material):—

South-west monsoon season:

7°– 9° N between 75°–78° E, Wadge bank

11°–15° N between 73°–76° E, shelf

11°–13° N between 72°–74° E, shelf

North-east monsoon season:

7°–10° N between 75°–78° E, shelf

10°–13° N between 71°–74° E, Laccadive area.

The observations made during the IIOE (R.V. *Vityaz*) indicated rich patches of phytoplankton in the following regions: south of Java, the region between Indonesia and North-west Australia, south of Bay of Bengal, Andaman Sea, Aden Bay and region between Bombay and Mangalore. During south-west monsoon, the quantity of phytoplankton was two to two-and-a-half times richer than during north-east monsoon. Regions of rich plankton were those with upwelling.

Zooplankton

The zooplankton biomass in the Arabian Sea during the south-west monsoon months has been found to differ considerably in the oceanic and neritic waters (Prasad, 1968 *a, b*). It is relatively high in the Laccadive Sea and the south-west coast of India, being 25 ml/m² to more than 50 ml/m² in the inshore waters between Calicut and Quilon. During the period it is found to be less than 5 ml/m² in the shelf areas from north of Bombay to Karachi coast. Zooplankton biomass is low, less than 5 ml/m², in the Central Arabian Sea and Central South Arabian Sea especially in 5° square, 15°–10° N and 65°–70° E.

During the north-east monsoon months the zooplankton biomass in the Arabian Sea section under consideration is relatively lower, being less than 25 ml/m² and still lower (less than 10 ml/m²) along the Bombay Coast. However, biomass is high (more than 50 ml/m²) in the inshore waters between Calicut and Quilon.

The biomass is low (less than 5 ml/m²) in the area between 10° and 45° S and 60° and 95° E. The biomass is high (more than 50 ml/m²) south of Ceylon especially in the 5° square 0° to 5° N and 80° to 85° E.

During the south-west monsoon, in the Bay of Bengal the biomass is low (less than 10 ml/m²) in the 5° square 10° to 15° N and 85° to 90° E, and the biomass is low west of Sumatra, in the 5° square 0° to 5° N and 90° to 100° E. It is about 15 ml/m² in the Andaman Sea and the Madras Coast, but is relatively poor (10 ml/m² to 15 ml/m²) off the Andhra and part of Orissa Coast, but high in the upper part of the Bay of Bengal especially above 20° N.

During north-east monsoon the plankton biomass is high in the south-west part of the Bay of Bengal in the 5° square 10° to 15° N and 80° to 85° E. It is about 15 ml/m² in the central part of the Bay of Bengal and about 10 ml/m² in the Andaman Sea. During the period the biomass is low west of Sumatra and also in the Gulf of Martaban.

Benthic fauna

Very little information is available about the benthic fauna of this region. Some valuable data have been collected for an inshore region off Calicut on the West Coast of India where work had been carried out from 1959 to 1967. In this area on an average the 4 and 6 fathom belts are richer than the 2 and 8 fathom belt and colonisation of the bottom generally commences immediately after the cessation of the south-west monsoon, attaining a maximum during the January-March period. *Prionospio pinnata* (Polychaeta, Spionidae), *Disoma orissae* (Polychaeta, Disomidae), *Pholas orientalis* (Mollusca, Lamellibranchiata) and *Clymene* (*Euclymene*) *watsoni* (Polychaeta, Maldanidae) are the four organisms that are at times found in abundance dominating the fauna. At the same time *Lumbriconereis bifilaris* (Polychaeta, Eunicidae) is present though not in abundance throughout the year. The qualitative fluctuations of the bottom fauna does not follow the same pattern every year. In the same area meroplankters are generally common during April–September, while their abundance in some years in January–March is also noted. The dominant constituent of the bottom fauna is usually found in the gut contents of the Malabar sole (*Cynoglossus sp.*), which supports a minor fishery in the area.

Investigations carried out farther south off Trivandrum show that fine sand with mud and calcarious deposits seem to be the best ground for bottom macrofauna, mostly crustaceans. Stomach contents of bottom feeding fishes show that they feed on mysids, cumaceans, sergestids and other crustaceans and polychaetes.

Fisheries

The estimates of demersal and pelagic fish landed in 1966 in different countries according to regional subdivisions are shown in Tables III and IV. The basic data for most of the estimates are taken from the *F.A.O. Year Book* 1966. The basis of region-wise and category-wise subdivision of the data is explained in notes following the above two tables.

Potential Yield

Demersal Fish

A correct appraisal of the potential yield from demersal stocks can be made in many ways. If the identities of various stocks of the different species together with relevant vital rates are known then it is possible to make an exact assessment of exploited stock and derive the optimum catch that can be obtained from each stock and thus the optimum catch from the entire demersal stock. Secondly, exploratory survey in different areas and depth zones may also give indication of the potential yield from demersal stocks. Thirdly, we may get some idea of the total potential yield from the productivity studies and then separate the contribution of demersal stocks. Lastly, we

TABLE III

Catch from exploited stock

Region		Arabian and Laccadive Seas				
		Estimated catch, 1966 (m. tonnes)			Catch of demersal fish per hectare of shelf area	
		Demersal	Pelagic	Total	upto 50 m.	upto 200 m.
1. West Pakistan	..	98,000	44,000	142,000	49·4	18·4
2. India						
Gujarat	..	20,200	60,100	80,300	3·1	2·0
Maharashtra	..	80,600	53,700	134,300	31·6	7·7
Goa	..	5,500	19,300	24,800	19·3	5·5
Mysore	..	7,400	58,200	65,600	9·3	2·9
Kerala	..	62,800	283,900	346,700	50·0	17·5
Madras (West Coast)	..	7,400	17,600	25,000	87·7	9·5
Laccadives	..	250	400	650		0·6
3. Maldives	..	Nil	12,000	12,000		
TOTAL	..	282,150	549,200	831,350		

TABLE IV

Catch from exploited stock

Region		Bay of Bengal, Andaman Seas and Singapore Straits				
		Estimated catch, 1966 (m. tonnes)			Catch of demersal fish per hectare of shelf area	
		Demersal	Pelagic	Total	upto 50 m.	upto 200 m.
1. Burma	..	108,000	108,000	216,000	10·0	5·0
2. East Pakistan	..	24,500	8,700	33,200	6·6	3·7
3. India						
West Bengal and Orissa	..	3,300	6,700	10,000	1·2	0·7
Andhra	..	21,100	59,000	80,100	12·7	6·8
Madras (East Coast)	..	36,700	73,100	109,800 }	16·4	14·8
Pondicherry	..	4,500	8,200	12,700 }		
Andaman and Nicobar	..	100	200	300		0·1
4. Ceylon						
West coast	..	25,400	47,400	72,800	28·1	18·7
East Coast	..	8,500	15,800	24,300	18·0	7·3
5. Thailand						
West Coast	..	13,100	9,200	22,300	6·2	2·3
TOTAL	..	245,200	336,300	581,500		

Notes: (1) The total catch of marine fish in Pakistan in 1966 as given in the *F.A.O. Year Book* is 180·2 thousand tonnes. This includes 5·0 thousand tonnes of freshwater prawns. Excluding the same, the total marine catch is 175·2 thousand tonnes. The share of demersal catch (consisting of groups: flat-fishes, percoid fishes, elasmobranchs and prawns) comes to 122·5 thousand tonnes, and that of pelagic catch to 52·7 thousand tonnes. The break up between West Pakistan and East Pakistan is not known. Probably, it may be assumed that as in the case of India about 80% of the total demersal catch comes from West Pakistan waters, *i.e.*, a demersal catch of 98·0 thousand tonnes, the balance of 24·5 thousand tonnes having been assumed to be the share of East Pakistan, where there is a good trawl fishery for threadfins, *Polynemus indicus*.

Of the total pelagic catch of 52·7 thousand tonnes in Pakistan it is assumed that almost the entire catch of shad group comes from East Pakistan and the balance may have come from West Pakistan.

(2) Detailed category-wise estimates of marine fish are available for each of the constituent Status of India. The figures given in Tables III and IV for the various States in India are taken from those available estimates. The following categories of fish have been included under the demersal group: Elasmobranchs, Eels, Cat. fishes, Perches, Red Mullets, Polynemids, Sciaenids, *Lactarius*, Soles, Prawns and 50% of the miscellaneous category

(3) The *F.A.O. Year Book* gives the 1966 Maldive catch as 12,000 tonnes. Details are not given. Most of the catch must be in tunas and other pelagic fishes. It is, therefore, assumed that almost the entire catch of Maldives consists of pelagic fishes.

(4) The total estimated catch of Laccadive-Minicoy islands was only 650 tonnes of which about 250 tonnes consisted of demersal fishes.

(5) The total marine catch of Ceylon in 1966 as given in the *F.A.O. Year Book* is 97·1 thousand tonnes From the classification of categories of fish caught, it is seen that demersal fish consists of 33·9 thousand tonnes and pelagic 63·2 thousand tonnes. As in the case of India, it is assumed that 75% of each category comes from the west coast of Ceylon.

(6) The *F.A.O. Year Book* shows the catch in 1966 in Burma as 360 thousand tonnes. Details regarding how much of it is marine catch is not given. Considering the position in the neighbouring country East Pakistan and considering also the big riverine resources of Burma, the marine catch may not exceed 60% of the total catch, *i.e.*, a catch of about 216 thousand tonnes. It is assumed that 50% of this consists of pelagic fish and the other 50% demersal.

(7) The catch for west coast of Thailand is taken from the *F.A.O. Year Book*.

may also estimate the potential yield of an area by comparing with another area where full exploitation has been carried out and the potential yield from which is known.

For all areas considered in the Central Indian Ocean region it may not be possible to estimate potential yield based on all the methods described above due to lack of data. But attempts will be made to derive estimates from various approaches where such data are available.

West Pakistan

The total demersal catch is 98,000 tonnes. If we take the area of the continental shelf up to 200 m., the present catch of demersal fish is 18 kg. per hectare; or if it is assumed that the catch comes from the shelf area upto a depth of 50 m., it would be 49 kg. per hectare. Based on studies in the Gulf of Thailand Tiews (1966) has expressed that a sustained yield of about 48 kg. per hectare of demersal fish for the continental shelf up to 50 m. is possible for the south-east Asian countries. The present per hectare catch in West Pakistan exceeds the rate given by Tiews. If such a comparison is valid, no further increase is possible in the potential catch of demersal fish from the 50 m. continental shelf. Probably, some increase can be envisaged from 50 to 200 m. depth zone We can probably take 25 kg. per hectare for the entire continental shelf and arrive at a potential yield of 136,000 tonnes.

The status of various stocks constituting the demersal fishery is not known. Nothing is known about the productivity of the area. But if we assume the same productivity as in Maharashtra-Gujarat zone, *i.e.*, 1·22 Cg/m^2/day for 0–50 m. zone and 0·12 Cg/m^2/day for 50–200 m. zone, the potential fish production is 243,000 tonnes. If 80% of this is considered as at present, demersal fish, the potential demersal yield will be 194,000 tonnes, *i.e.*, about 35 kg. per hectare for the continental shelf. Taking an average of 30 kg. per hectare, the potential yield would be 163,000 tonnes, This does not seem to be an unreasonable estimate, particularly because the shelf area of West Pakistan is extremely rich in nutrients due to the discharge of Indus waters. It may be mentioned here that Tiews (1966) has estimated the total potential yield from West Pakistan shelf area to be 210,000 tonnes.

India

Gujarat and Maharashtra.—The present catch in Gujarat shelf is 30,200 tonnes and that in Maharashtra shelf is 80,600 tonnes with a combined total catch of 110,800 tonnes. The major portion of this catch is taken by indigenous boats operating a fixed stake bag net within a narrow belt of 20 m. from the shore. Some commercial trawling is also done within the 50 m. depth.

The demersal catch consists of the following groups of fish: Elasmobranchs, eels, cat-fish, perches, red mullets, polynemids, sciaenids, *Lactarius*, pomfrets, sole, prawns and other miscellaneous fish. The catch as well as the catch per unit effort from both inshore and offshore fisheries definitely declined in case of *Polynemus indicus* and *Otolithoides brunneus* and eels. In case of other groups, no such declining trends have been noticed, suggesting that most of these demersal species are under-exploited, and a far higher potential yield than obtained at present could be expected. The depth-wise analysis of commercial trawls operated in Gujarat-Maharashtra waters during 1958 to 1962 indicate that though in general catch rate falls off beyond 40 m., in case of certain categories of fish like small sciaenids (*Dhoma*), eels and elasmobranchs the catch rate increases beyond 40 m. belt, and these areas are not being adequately fished at present. Hence, the total demersal catch from the shelf area can be substantially increased.

At present the catch per hectare in the shelf area up to 50 m, area of Gujarat is only 3·1 kg· and for Maharashtra 31·6 kg. The figure for Gujarat is low, as nearly half of the shelf area under 50 m. consists of very shallow waters. Even neglecting the same, the catch per hectare within 50 m. depth for Gujarat will be about 6 kg. per hectare. Considering that most of the shelf area remain unexploited and most of the demersal fish stock remain underfished at present, a catch of 15 kg. per hectare for Gujarat and 25 kg. per hectare for Maharashtra will not be unreasonable.

Mysore and Goa.—No special effort is made to fish for demersal fishes, but a little quantity of it is caught along with pelagic fish with the help of shore seines and boat seines. The fishing is restricted to coastal waters. Only recently some small motorised boats are operating from some centres for exploitation of prawns. Some exploratory shrimp trawling was done at Karwar with the help of 3 small vessels of H.P. varying from 24 to 90 and the catch rate per hour was 191·95 kg. This compares very favourably with catch rates obtained with bigger vessels in Gujarat-Maharashtra area. Very little prawn was obtained in the experimental hauls. *Opisthopterus tardoore* and *Leiognathus* formed more than 50% of the catches along with sizable catch of *Lactarius*, sciaenids and sharks and rays. None of these species are now exploited to any degree in the inshore waters. The results of the experimental trawls indicate good trawling grounds within 50 m. depth and if such grounds are exploited, a substantial quantity of demersal fish can be obtained from the shelf area of Mysore and Goa. At present the catch per hectare up to 50 m. depth is 19·3 kg. for Goa and 9·3 kg. for Mysore. Since no exploitation of ground fish beyond the coastal waters is made, it is reasonable to expect a catch of 15 kg. per hectare for the entire shelf area for Goa and Mysore.

Kerala.—Demersal fish and prawns are exploited by indigenous vessels in the inshore water within 20 m. depth and also by about 2,000 motorised boats in waters up to 50 m. depth. Demersal catch forms less than 20% of the total landings. The main groups of demersal fish landed are prawns, elasmobranchs, cat-fish, sciaenids, soles and other miscellaneous fish. Prawns form about 45% of the demersal catch. The catch per unit effort, and the mean size of prawn in the commercial catch show decline, but the catch does not show any increase along with increase of effort. So, probably, we are now catching the optimum quantity of prawns and any further exploitation may affect the stock. For the other demersal species, no declining trend in catch or catch per unit effort are noticed and hence it is possible to increase their catch to some extent. At present, the catch per hectare for the shelf area below 50 m. works out to be 50 kg. and 17·5 kg. for the entire shelf·

The evidences are that waters up to 50 m. belt are now heavily fished and only increase can come by fishing in the 50–200 m. zone of the continental shelf. Probably a sustained yield at 25 kg. can be obtained per hectare from the shelf area.

Madras and Andhra.—In the west coast of Madras, the fishing is now entirely restricted to coastal waters. The 50 m. contour is very near the shore and the catch per hectare is very high, *viz.*, 88 kg. But the water beyond 50 m. remains unexplored. At present the catch per hectare for the continental shelf is only about 9·5 kg. Perches, sciaenids, elasmobranchs and cat-fishes form the main demersal fishery. No declining trend is noticed. It is possible to expand the fishery beyond the 50 m. depth and increase the yield of demersal fish. Probably a catch of 30 kg. per hectare of demersal fish can be obtained from the area.

On the east coast, demersal fish is at present caught in inshore waters with shore seines and boat seines. Deeper waters are not exploited at present. Some experimental fishing done from Tuticorin and Waltair show good catch rates, though not as high as in the west coast. Exploitation of the shelf area will open up new unexploited grounds of demersal fish. In fact, experimental trawling in Mandapam area showed very encouraging results. At present the catch per hectare in the shelf area up to 50 m. depth is 16·4 kg. for Madras and 12·7 kg. for Andhra. The per hectare catch for these two States for the whole shelf area are 14·8 kg. and 6·8 kg. These can be substantially increased. Probably, a sustained yield of 15 kg. per hectare for the entire shelf area will be a reasonable figure.

Orissa and West Bengal.—Fishing is done only in areas of tidal influence and practically the entire continental shelf remains unexploited. It is thus reasonable to assume a catch of 15 kg. per hectare for Andhra and Madras shelf area and a catch of 10 kg. per hectare for Orissa and West Bengal. The potential catch of demersal fish based on the above rates is given in Table VI and works out to 577,000 tonnes for the west coast and 143,000 tonnes for the east coast of India.

TABLE V

Productivity studies

Region		Cg/m²/day		Potential catch (thousand tonnes)
		0–50 m.	50–200 m.	
Maharashtra-Gujarat	..	1·21	0·12	1,062
Mysore-Goa	..	1·08	0·19	140
Madras (West Coast)	..	1·33	0·37	32
Kerala	..	1·22	0·25	183
East Coast	..	1·21	0·48	871
TOTAL				2,288

For verification of the reasonableness of the above results we have computed the potential yield from the results of productivity studies carried out in the Institute. The average productivity of carbon of the two depth zones are given for the shelf area of the different States in Table V The east coast data are from the Indian Ocean Expedition. No figure for 0–50 m. zone in Mahar·shtra-Gujarat is available, but we have assumed it to be an average figure of 1·21. From these afigures the potential yield of fish has been worked out as follows: In heavily exploited areas elsewhere where optimum catch is obtained it has been observed that carbon content of optimum fish catch divided by net carbon production which is 60% of gross carbon production gives a ratio 0·004. Hence, the potential yield is 0·024 C where C is the gross carbon production. Thus for example, for a carbon production of 1·22 $Cg/m^2/day$, the annual potential yield of fish is 105 kg. per hectare. The potential yield of fish for the entire continental shelf area of India has been worked out in Table V and comes to 2,288,000 tonnes, of which the share of west coast is 1,417,000 tonnes. Subrahmanyan (1959) on the basis of phytoplankton production and its relation to catch has estimated a potential yield of about 1,120,000 tonnes for the west coast of India. Both the above estimates include both pelagic and demersal fish. At present, the demersal catch is about 28% of the total catch. If the same ratio is maintained, the potential demersal catch for the entire Indian shelf area will be 640,000 tonnes and the potential pelagic yield about 1,648,000 tonnes.

TABLE VI

Estimated demersal catch

Countries/ States	Shelf area (1,000 hactares)	Present catch (1,000 tonnes)	Catch (Kg.)/hectare Present	Potential	Potential catch (1,000 tonnes)	
West Pakistan ..	5,440	98	18·0	30	..	163
India—West Coast						
Gujarat ..	9,937	20	2·0	15	149	
Maharashtra ..	10,476	81	7·7	25	262	
Mysore ..	2,547	7	2·9	15	53	
Goa ..	998	6	5·5			
Kerala ..	3,594	63	17·5	25	90	
Madras (West Coast) ..	780	7	9·5	30	23	720
India—East Coast						
Madras (including Pondicherry) ..	3,362	41	14·8	15	50	
Andhra ..	3,104	21	6·8	15	47	
Orissa ..	2,363	3	0·7	10	46	
West Bengal ..	2,286					
East Pakistan ..	6,555	24	3·7	15		98
Burma ..	21,750	108	5·0	15		326
Ceylon						
East Coast ..	1,170	9	7·3	15	18	52
West Coast ..	1,358	25	18·7	25	34	
Thailand—West Coast ..	5,806	13	2·3	10		58
Islands						
Andamans ..	1,533	neg.	..			
Nicobar ..	73	neg.	..			
Laccadives ..	434	neg.	..			
Maldives ..	745	neg.	..			

Even though potential yield has been shown separately for each State, it is not correct to do such separation, since pelagic fish subjected to wide migration may utilize food over a wider region. Hence, it is safer to consider the region as a whole or at least separately for the two coastal regions.

Thus it will be seen that the estimate of 640,000 tonnes of potential demersal catch arrived at from the productivity studies is nearer to the estimate of 720,000 tonnes arrived at from consideration of present level of exploitation and the status of stocks. A reasonable estimate of potential yield of demersal fish may be about 650–700 thousand tonnes.

East Pakistan

At present the shelf area is not much exploited for demersal fishes. Some are caught near the inshore waters. If we consider the shelf area under 50 m. depth, a catch of 6·6 kg. per hectare is obtained and 3·7 kg. per hectare if the entire shelf is considered. But considering the fact that no exploitation takes place at present, the potential yield per hectare would be far higher than any of the above figures. If the productivity index of the Bay of Bengal is applicable to East Pakistan shelf area, the estimate of the total production of fish is obtained at 500,000 tonnes. If 50% of this consists of demersal fish, it will mean a demersal yield of about 38 kg. per hectare of the shelf area. This is not an unreasonable figure. But since the area remains unexplored at present and considering the geography of the coast line, a potential yield of 15 kg. per hectare can be reasonably considered. The estimate of potential yield on the basis of 15 kg. per hectare for the entire continental slope comes to about 98,000 tonnes. This compares favourably with the estimate of 120,000 tonnes arrived at by Tiews (1966).

Burma

The present catch rate for Burma is 10 kg. per hectare for 50 m. shelf area and 5 kg. per hectare for the entire shelf. No offshore exploration takes place at all. The shelf area is known to be rich. A much higher yield per hectare than any of the above figure can be maintained. If the productivity figures of Bay of Bengal area are applicable to the Burma shelf area, we could expect a potential yield of about 1,575,000 tonnes. If half of this, *i.e.*, about 800 thousand tonnes is demersal, then a yield of about 38 kg. per hectare could be expected. However, for the time being, the reasonable figure of 15 kg. per hectare may be accepted, giving a potential yield of about 326,000 tonnes. Tiews (1966) estimated the potential yield of demersal fish from the continental shelf area of Burma as 370,000 tonnes.

Ceylon

At present the catch per hectare in the shelf area up to 50 m. on the west coast of Ceylon is 28·1 kg. per hectare and it is 18·7 kg. if the entire shelf area is considered. On the east coast, the corresponding figures are only 18·0 kg. and 7·3 kg. respectively. On the basis of 15 kg. per hectare for the east coast shelf area and 25 kg. per hectare for the west coast shelf, the potential yield of demersal fish for Ceylon comes to 52,000 tonnes. Tiews (1966) has furnished an estimate of 60,000 tonnes of demersal fish yield for the whole of Ceylon. From the available productivity data, it is estimated that the shelf area of Ceylon can probably support 180,000 tonnes of total yield; of which the demersal contribution will be about 60,000 tonnes, if the present ratio of 33% of demersal catch to total catch is maintained. This is similar to the earlier two estimates.

Thailand (West Coast)

The fishery resources along the west coast of Thailand are virtually untapped. Tiews (1966) has estimated the potential yield of demersal fishes in these waters to exceed 2·5 times the present yield, and its magnitude will be about 56,000 tonnes. At present yield per hectare up to 50 m. depth contour is 6·2 kg. and only 2·3 kg. if the entire shelf area is considered. If it is assumed that 10 kg. per hectare can be obtained, the expected yield from the shelf area is about 58,000 tonnes.

Pelagic Fish

The estimated pelagic catch from the west coast of India in 1966 was about 493,000 tonnes and about 73,000 tonnes from east coast.

The landings from the major pelagic species on the west coast were as follows

Oil sardine	..	247,000 tonnes
Mackerel	..	27,000 tonnes
Bombay-duck	..	77,000 tonnes

These three species together constitute nearly 70% of the total pelagic landings of the west coast of India.

The fisheries for oil sardine and mackerel are characterised for their wide annual fluctuations. The prevailing view is that these fluctuations are caused by variations in accessibility of the stocks due to the severely restricted fishing range at present and these variations in accessibility represent changes in the disposition of the migratory paths taken by the fish. It is not known what fraction of these stocks are exploited at present even during years of maximum availability. Assuming availability to be the same for all years our studies have shown that we are still below the optimum sustainable yield. If, however, we are exploiting only a fraction of the stocks, our present catch will be very much below the potential yield.

The total annual catch of Bombay-duck has declined somewhat during the last decade. But in the absence of correct effort data, we cannot say if catch per effort has declined. The fishing is by fixed stake bag net and hence it is possible that the catch depends on the availability. The species is neretic-pelagic, one having a long migration circuit still unknown. Hence, it is likely that the present catch is much lower than the potential yield.

From the productivity studies, it was estimated that the total potential yield of pelagic fisheries on the west coast is about 1,020,000 tonnes, *i.e.*, a little more than double the present pelagic catch. It is thus possible that the potential increase may come entirely from these three important pelagic resources or from the other numerous small pelagic resources which may not be fully exploited at present.

On the east coast, the total landings of pelagic fish come to 73 thousand tonnes. There are many small pelagic stocks from which the catch comes. Most of these stocks are underexploited at present. The productivity studies indicate the potential pelagic catch from the east coast to be about 672,000 tonnes.

Rough estimates of potential pelagic yield for other areas are also given in Table VII.

West Pakistan

In West Pakistan the total pelagic landings in 1966 were estimated at 44,000 tonnes. Of these oil sardine landings were about 9,000 tonnes, and tuna landings 12,000 tonnes and mackerel and bill fish landings about 13,000 tonnes. The landings of each of these show a rising trend since 1962. No effort figures are available. But still from the rising trend in catch, it is reasonable to conclude that the potential yield from these pelagic stocks will be much higher than the present catch. A conservative estimate will be double the present catch. Thus the potential yield of all pelagic fish may be taken at 88 to 90 thousand tonnes. It has already been stated that Tiews estimated a total potential yield of about 210,000 tonnes from the shelf area of West Pakistan. Accepting the present estimate of 90,000 tonnes of pelagic fish and 163,000 tonnes of demersal fish, the estimate of total potential yield arrived in this paper is 253,000 tonnes.

East Pakistan

The present landings consist almost entirely of *Hilsa* and other pelagic resources are not very much exploited. It is difficult to estimate the potential yield of pelagic fishes in the area. It has been shown earlier that the estimate of total fish yield as derived from carbon productivity index in various depth zones in the Bay of Bengal area is supposed to be about 500,000 tonnes and about 50% of the same may be in pelagic fish. At least half of this will be reasonable figure.

Burma

The very rough estimate of pelagic landings in Burma is about 108,000 tonnes at present. The estimated potential yield of pelagic fisheries from productivity studies was found at about 800,000 tonnes. At least half of it will be a reasonable figure.

Ceylon

From productivity figures, the total potential yield for Ceylon was estimated at 180,000 tonnes out of which 60,000 tonnes were in demersal fish. Thus the potential yield of pelagic fish comes to about 120,000 tonnes. The present yield of pelagic fishes in Ceylon is about 63,000 tonnes. Hence, a reasonable estimate of 90,000 tonnes of pelagic fish as potential yield would not be very unrealistic.

Thailand—West Coast

There are absolutely no data to make any estimate regarding the potential yield of pelagic fisheries. It will be probably realistic to expect that the present yield of 9,200 tonnes can be doubled, particularly since the resources in these waters are virtually untapped and the potential yield assumed to be 20,000 tonnes.

Potential Yield from the Island Groups

Andaman and Nicobar Islands

At present commercial fishing is carried out only from Port Blair and it amounts to 300 tonnes consisting of 100 tonnes of demersal fish and 200 tonnes of pelagic fish. In the rest of the island regions, only subsistence fishing is carried out. These island groups have a continental shelf of about 16,000 sq. km. Even at the rate of 2·5 kg. per hectare, a potential yield of about 4,000 tonnes of demersal fish could be derived. On the basis of the present composition the potential yield of pelagic fish could be increased to 8,000 tonnes.

Laccadives

The present yield from the Laccadives is only 650 tonnes. Of this about a third consists of tuna. Excepting for some tuna fishing by pole and line, the fishery resources of the islands are virtually untapped. At the rate of 2·5 kg. per hectare, the potential yield from the shelf area of the island will be about 1,100 tonnes of demersal fish. On the basis of the present composition the pelagic fish yield could be 2,200 tonnes.

Maldives

The present yield from the Maldives is about 12,000 tonnes and consists generally of tunas and other pelagic fish. At the rate of 2·5 kg. per hectare, the potential yield for demersal fishes could be 1,800 tonnes. It is difficult to make any assessment of pelagic yield.

St. Pauls and New Amsterdam

At present the annual catch consists of 212 tonnes of spiny lobster and the fishing for lobster has probably reached the maximum limit (Silas, 1967). The other resources are yet untapped.

Chagos Archipelago

No data are available. For this group and St. Paul and Amsterdam island, a potential yield of 0·2 thousand tonnes of demersal fish and 0·3 thousand tonnes of pelagic fish has been assumed.

Thus for the various island groups considered above, probably 7,000 tonnes of demersal fish and 22,000 tonnes of pelagic fish can be obtained.

POTENTIAL YIELD FROM THE OCEANIC AREA

The following Table shows the area and the tuna landings in the three oceans.

	Pacific Ocean	Atlantic Ocean	Indian Ocean
Area in 1,000 km. ..	165,246	82,441	73,443
Landing of tuna (in 1,000 tonnes) ..	840	257	150
Landing in kg. per hectare ..	0·0583	0·0311	0·0204

The Pacific Ocean has been exploited to a great extent for the tuna compared to the other two oceans. Except for the yellow-fin tuna, the landings of other species in the Pacific as a whole have been less than the maximum sustainable yield from the Pacific stocks and as such still further yield from the Pacific could be expected. However, for the purpose of this paper, we will assume that maximum sustainable yield is now being obtained from the Pacific. If so, we can expect a catch of 0·0583 kg., *i.e.*, about 0·06 kg. per hectare of the ocean area. The present catch per hectare in the Indian Ocean is about 0·02 kg., *i.e.*, about one-third of the potential yield. For the Central Indian Ocean region considered here, the potential yield at the rate of 0·06 kg. per hectare would be:

$$2{,}47{,}66{,}000 \times 100 \times 0{\cdot}06 = 149{,}000 \text{ m. tonnes (taking shelf area into consideration)}$$

$$2{,}39{,}23{,}000 \times 100 \times 0{\cdot}06 = 144{,}500 \text{ m. tonnes (not taking shelf area into consideration)}$$

as against the present estimated catch of 49,000 m. tonnes from this region.

Thus the final position is given in Table VII.

TABLE VII

Potential yield

	Potential yield (1,000 tonnes)		
	Demersal	Pelagic	Total
Mainland			
West Pakistan ..	163	90	253
East Pakistan ..	98	250	348
India—			
West Coast ..	577	1,020	1,597
East Coast ..	143	672	815
Burma ..	326	400	726
Ceylon ..	52	90	142
Thailand—West Coast ..	58	20	78
Islands ..	7	22	29
Open Sea ..		144	144
TOTAL ..	1,424	2,708	4,132

From Tables III and IV, it will be seen that the annual yield in 1966 from the continental shelf areas of Arabian Sea, Laccadive Sea, Bay of Bengal, Burma Sea and Malacca Straits falling within the Central Indian Ocean region is composed of

Demersal fish	..	527,350 tonnes
Pelagic fish	..	885,500 tonnes

The present catch from the Chagos, St. Paul and New Amsterdam is estimated at 300 tonnes of demersal fish. The oceanic catch of the entire Indian Ocean is about 150,000 tonnes. It is therefore assumed that the yield from the Central Indian Ocean region considered here being one-third of the entire Indian Ocean is about 50,000 tonnes. Thus the current yield from the entire region is as follows (in round figures):

Demersal fish	..	527,000 tonnes
Pelagic fish	..	936,000 tonnes
TOTAL	..	1,463,000 tonnes

From Table VII, it will be seen that the potential yield from the region is about 3 times the current yield. Both demersal and pelagic yield can be increased about threefold individually.

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